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Making matters? Unpacking the role of practical aesthetic making activities in the general education through the theoretical lens of embodied learning

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Abstract: New knowledge on cognition and learning generated in the various fields of neuroscience is now being incorporated into the learning sciences. This development might have broad significance for the theoretical development of the field of education, in particular leading to a renewed and more nuanced understanding of learning as an embodied process. The Nordic countries have a long and rich tradition of including arts and crafts as core subjects in children's education; however, there is an ongoing discussion of its potential role in the twenty-first century. The new knowledge on cognition and learning opens up new vistas on practical-aesthetic "making" activities in the general education of children. This article establishes a theoretical lens of *embodied learning* as an operational translational framework for questioning the assumption that "making matters" and uses it as a tentative analytical tool to unpack an example of making activities.

Subjects: Educational Research; Theories of Learning; Arts; Art & Visual Culture

Keywords: making; arts education; neuroscience; learning sciences; translational work; interdisciplinarity

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ABOUT THE AUTHOR

Marte S. Gulliksen PhD is a researcher and teacher at University College of Southeast Norway, Campus Notodden. She leads the research group Embodied Making and Learning, an interdisciplinary initiative with more than thirty members across three departments. Marte's top expertise is on "embodied making and learning", "arts and craft as sociocultural practice" and "culture education". Coming from a background of teacher education, music and craft, her interdisciplinary research interest has led her to implementing neuroscientific knowledge in her studies of learning and making, and exploring the epistemological and methodological challenges this entails. Currently, she is leading an international group of researchers in such an interdisciplinary study of embodied learning, developed partly through her previous experience as Guest Professor at Iceland University (2013–2016) and as member of the Human Ingenuity Research Group at Western University, Canada. This article is a part of the conceptual framework for this current study.

PUBLIC INTEREST STATEMENT

Humans have always made tools for mastering our environment, and are still, everyday, making things, like sketching ideas on paper in board meetings to get their message through. But when it comes to education and schools, some experts claim that arts are important to learn in school and some not. How do teachers and policymakers navigate in this complex terrain? Which scientists should policymakers believe? This article presents a framework, embodied learning, for analyzing and understanding making processes. This framework brings together and translates between neuroscience, learning sciences, making disciplines and arts education research. Using this framework to analyze what a 7-year old girl learn while making a flute in green willow, the article aims to give meaningful understanding of how making activities influence a child's learning. Exemplifying ways that making matters, the article is useful for scientists, teachers and policymakers interested in improving educational outcome.

New knowledge on cognition and learning generated in the various fields of neuroscience is now being incorporated in the learning sciences. This development might have broad significance for the theoretical development of the field of education, in particular leading to a renewed and more nuanced understanding of learning as an embodied process. The Nordic countries have a long and rich tradition of including arts and crafts as core subjects in children's education; however, there is an ongoing discussion of its potential role in the twenty-first century. Questioning the assumption "making matters," this article aims to convey and conceptualize this new development by (1) developing a theoretical lens of embodied learning and (2) using it as a tentative analytical tool to unpack an example of making activities.

Making is a core activity for humans in mastering their environment (Ingold, 2013), from the first humans making tools used to make fire and weapons, harvest crops, or make shelters, to humans of today making bridges and buildings or sketching ideas on paper in a board meeting. Through the act of making something, humans constantly adapt to, and master, our environment, changing it to better suit our needs (Michl & Dunin-Woyseth, 2001). This hands-on engagement is widely recognized, for example by EU, as necessary for a creative and innovative Europe (AECEA, 2009). Making is also a social activity: as we make, we try to understand our surroundings and understand others. In making physical things or making sounds, words and songs, we communicate with others and make meaning together (Wenger, 2008). This joint meaning-making is often referred to as "culture," defined as the sphere within which various groups and individuals think, communicate, and act. As such, we are "both created by the culture that creates us, and creators of it" (Østerud, 1994, p. 404).

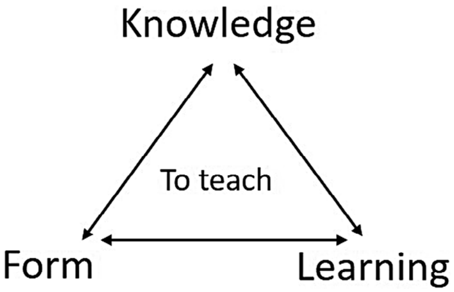
Practical aesthetic acts of making can be found in a variety of arts subjects in schools (e.g. Utdanningsdirektoratet, 2006). However, although the Nordic countries have a strong tradition of arts and crafts, as well as making, in schools, the role of making in twenty-first century schools is now challenged. According to OECD (2009, 2016), the percentage of time spent on arts subjects has decreased drastically from 2007 to 2016. For example, in Denmark, the percentage of arts subjects in primary education has been reduced from 20 to 8%, and in secondary education the arts have fallen from 11% to being an elective subject chosen by only some students. The trend is similar in all Nordic countries.

In the present global educational situation, which emphasizes educational accountability and learning outcomes, the topic of making activities is challenging. Studies indicate that the arts subjects in Nordic countries are regarded as pleasant but not very important in schools (Bamford, 2006). In contrast, there has been a new surge of interest in making in informal learning sites (such as "makerspaces"). What formal and informal making activities have in common is the hands-on-approach, sensory-motor interaction and learning activities endorsed in the tradition following, for example, Dewey (1958) and Eisner (1998). Given the new theoretical developments in the learning sciences emphasizing the biological foundations of learning, it is now possible to reassess making activities and see them anew. How can we understand them with this new lens?

1. Part 1. Developing the theoretical lens: Embodied learning

The expert competency of the teacher, to teach, as illustrated in Figure 1, is to decide which *form* — that is, what teaching and learning methods — should be used to support the student's *learning*

Figure 1. The teaching triangle (von Oettingen, 2016).



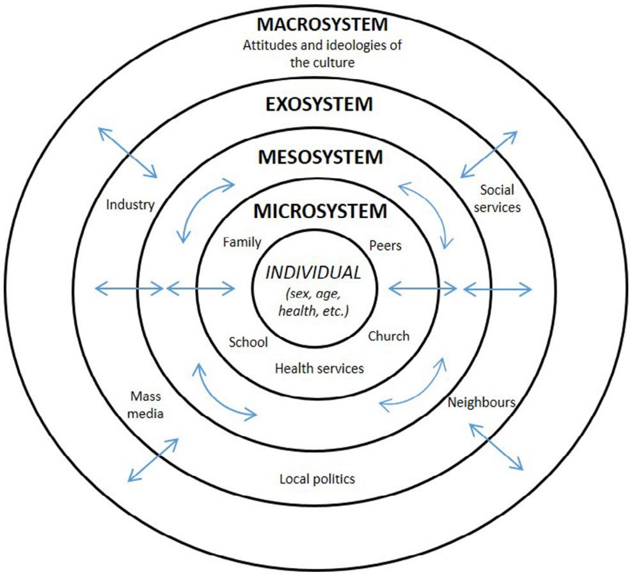


Figure 2. The ecological systems theory (Bronfenbrenner, 1979).

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of certain *knowledge*, information, or skills. To make good choices with regard to form, the teacher needs to know as much as possible about how her students learn.

1.1. Learning as change

There are a number of different taxonomies, definitions and theories of learning. However, they share some commonalities. In its broadest sense, learning is defined as a basic, adaptive function of humans (NRC, 2000). This adaptive function, also understood as purposeful change, is developed in a sociocultural context. Within educational sciences, we often study learning in classrooms or other sociocultural contexts. The Ecological systems theory of Bronfenbrenner (1979) is an example of one much-used tool for understanding and analyzing how the different systems, micro-/meso-/exo-/macro-systems, interact, with the individual in the centre (see Figure 2).

Learning as a process of change within such sociocultural contexts is related to a broad range of theories of learning as activity. For example, Engeström, Miettinen, and Punamäki-Gitai (1999) present in their seminal book "Perspectives on activity theory" a comprehensive framework for understanding a person's motivated and directed activity towards an object. Building on a Vygotskyan tradition, the outcome of this process in a learning context can be knowledge or experience. Mediated by artifacts, organization, or community, the activity itself is regulated or organized by rules and divisions of effort in the sociocultural context (Greeno & Engeström, 2014). Similar ways of describing learning as an activity have given birth to several new analytical approaches to describing learning, for example, that of Scardamalia and Bereiter, who describe learners as *creators of knowledge* (2014), and the term *actionable knowledge*, as discussed by Markauskaite and Goodyear (2016). Empirical research efforts, for example, the Co4Lab-project in Finland, http://co4lab.helsinki.fi/, are now being conducted in an effort to describe how the knowledge creation–collaborative learning approach can be implemented in an everyday context in schools. Such studies carry the promise of describing learning environments that can foster deep learning, for example, that described by Ohlsson (2011) as non-monotonic, a type of learning necessary for society's future social-creative knowledge work practices.

Recent advances in the neurosciences have helped us gain traction in understanding what is going on within the learning individual, that is, within Bronfenbrenner's inner circle. This is referred to as the fundamentally biological process of learning. Learning sciences incorporate this kind of knowledge when they aim to understand the nature of learning from a broad range of perspectives and to use this knowledge to shape the ways that learning environments and resources are designed and used (Palghat, Horvath, & Lodge, 2017; Sawyer, 2014). A new field of enquiry, educational

Figure 3. Proposed layered abstraction framework for the learning sciences

Source: Donoghue & Horvath, (2016, p. 4) https://www.cogentoa.com/article/10.1080/2331186X.2016.1267422.

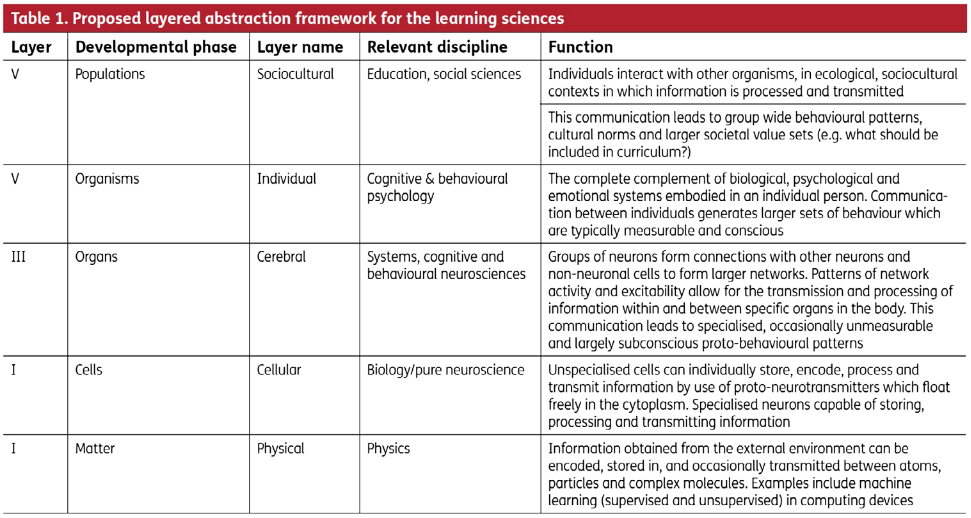


Table 1. Proposed layered abstraction framework for the learning sciences

Layer	Developmental phase	Layer name	Relevant discipline	Function
V	Populations	Sociocultural	Education, social sciences	Individuals interact with other organisms, in ecological, sociocultural contexts in which information is processed and transmitted This communication leads to group wide behavioural patterns, cultural norms and larger societal value sets (e.g. what should be included in curriculum?)
V	Organisms	Individual	Cognitive & behavioural psychology	The complete complement of biological, psychological and emotional systems embodied in an individual person. Communication between individuals generates larger sets of behaviour which are typically measurable and conscious
III	Organs	Cerebral	Systems, cognitive and behavioural neurosciences	Groups of neurons form connections with other neurons and non-neuronal cells to form larger networks. Patterns of network activity and excitability allow for the transmission and processing of information within and between specific organs in the body. This communication leads to specialised, occasionally unmeasurable and largely subconscious proto-behavioural patterns
I	Cells	Cellular	Biology/pure neuroscience	Unspecialised cells can individually store, encode, process and transmit information by use of proto-neurotransmitters which float freely in the cytoplasm. Specialised neurons capable of storing, processing and transmitting information
I	Matter	Physical	Physics	Information obtained from the external environment can be encoded, stored in, and occasionally transmitted between atoms, particles and complex molecules. Examples include machine learning (supervised and unsupervised) in computing devices

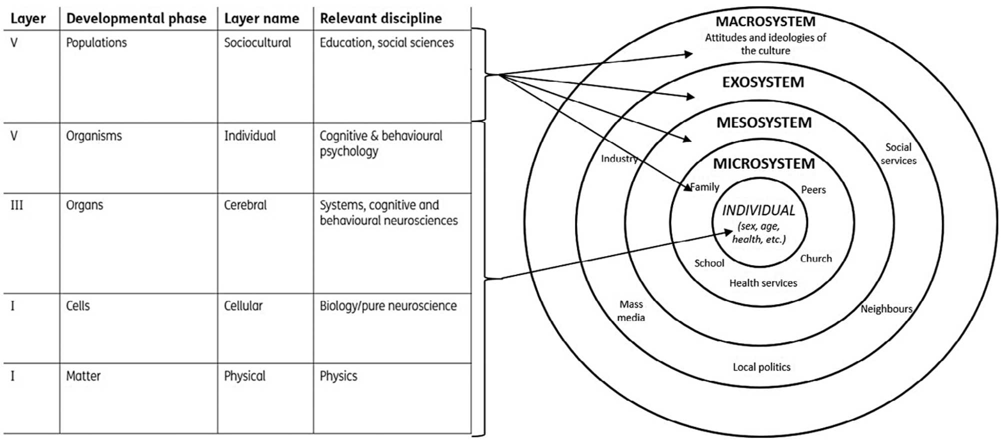
neuroscience, is evolving that has identified and addressed several issues with regard to how to combine this research in a constructive and valid way with psychological and sociocultural research on learning (Goswami, 2006; Wall, 2014).

1.2. Learning on different layers of complexity

Bringing together theories and knowledge from such a wide range of disciplines with different epistemological perspectives is challenging. In an acknowledgement of this, Donoghue and Horvath (2016) have developed the "layered abstraction framework" as a tool for translating between these perspectives (see Figure 3).

The framework presents learning in five layers, ordered by complexity. The simplest, lowest layer is the physical layer of matter: Singular atoms and biochemicals can store information and can therefore be said to learn. Neurons are a type of cell that stores and mediates information. They are a bit more complex, as they are comprised of biochemicals, which in turn are comprises of atoms, and as such are identified as learning on a cellular layer. Neurons works together in the peripheral and central nervous systems, most of which are in the brain, while some reach out across the rest of the body. So, at complexity level three, the brain is a highly complex organ that not only consists of neurons but also of other types of cells. In a third, cerebral level, these organs work together to communicate and store information, that is, to learn. The integration of organs results in an organism — complexity layer four. Organisms, or individuals, then conglomerate with each other as populations on the fifth, sociocultural, layer.

Figure 4. Difference in focus of the layers in the proposed abstraction framework and ecological systems theory.



Layer	Developmental phase	Layer name	Relevant discipline
V	Populations	Sociocultural	Education, social sciences
V	Organisms	Individual	Cognitive & behavioural psychology
III	Organs	Cerebral	Systems, cognitive and behavioural neurosciences
I	Cells	Cellular	Biology/pure neuroscience
I	Matter	Physical	Physics

The authors of this abstraction framework (Donoghue & Horvath, 2016) intended to distinguish between these layers of complexity and emphasize some logical assumptions between the layers. It is thus useful to remember that not everything we know of learning on the sociocultural or individual layer is included in this framework. Figure 4 visualizes some of the differences in focus.

The proposed layered abstraction framework for learning sciences is new and should be thoroughly discussed to explore its possibilities and limitations with regard to learning sciences. The present article is a contribution towards this. However, at this early stage, the framework has two main benefits: First, it makes it possible to discuss one aspect of learning at a time (one level of complexity), which is useful for supporting researchers navigating the complex field of learning as well as navigating between different disciplines (Palghat et al., 2017). Second, it makes it possible to understand some of the limitations of how far and in what way conclusions can be drawn, which is useful for avoiding neuromyths (see, e.g. Düvel, Wolf, & Reinhard, 2017) or other misguided uses of scientific research.

The framework includes descriptions of the relationships between layers. For example, the authors argue that phenomena on one layer cannot contradict phenomena established in a lower layer. This *downward compatibility* means that, for example, "for social learning theory (ecological, Layer V) to be true, it must be consistent with what is known about neural learning (Layer II) and could not rely upon a learning mechanism that has been disproved by neurology (e.g. a student's ability to mind-read)" (Donoghue & Horvath, 2016, p. 5).

Another feature of the framework is that even though something is established as true in one layer, it is not necessarily true in the layer above. This so-called *upward unpredictability* is due to the increasing complexity (by definition) of each level, which brings into play many additional mechanisms and influences. So, even though we know that one activity leads to significant neural activity in one area, this cannot be used to predict a theory on the social layer. For example, even though we know about the function of experience expectant neuroplasticity, we cannot assume that every experience will lead to the same changes in behaviour for every individual because there are so many other things that influence how an individual experiences a situation (dispositions, moods, attention, hunger/thirst and a variety of other factors).

Further, Donoghue and Horvath argue (2016, p. 5) that if we want to link the layers together and translate from one layer to another, we need to study each layer and see how they fit or do not fit together. We cannot make inferences based on a lower level, jumping between levels. The authors give an example of the need of *translational contiguity* by referring to a misguided commercial programme selling the idea that students in school should have a water bottle on their desk and should drink often, because it is documented that, on a cellular level, dehydration has an impact on neuronal function. However, this conclusion is misguided; it neglects the knowledge that on a cerebral level, individuals have other systems to ensure that cells are appropriately hydrated at all times. In addition, as anyone who has ever been in a classroom could predict, bringing as many water bottles as children into a classroom and having them stationed on desks is likely to have a range of other potential influences on individuals' learning.

1.3. Relationship between [cellular, cerebral] and [individual, sociocultural] layers: Embodied learning

Having presented the layered abstraction framework, we can proceed to a quick recap of some of the processes of learning in [cellular, cerebral] and on [individual, sociocultural] layers. One core learning function in the cellular and cerebral layers is neuroplasticity (Mason, 2011; Purves et al., 2012). As neurons process and transmit information in our bodies as electrical and chemical signals through synapses between cells, both cells and their connections are changed: they can grow if used and whither or disappear if not used. The two main types of neuroplasticity that are probably most important for the learning sciences are experience-expectant and experience-dependent plasticity. Experience-expectant plasticity is "the overproduction of synapses in specific areas of the brain at specific times, which are then organized and pruned by experiences that are expected or common to the human species" (Twardosz, 2012, p. 98). In education, we often refer to this as "sensitive periods," or stages in development when children are more sensitive to learning something, such as crawling. Experience-dependent plasticity, in contrast, is "the modification of existing synapses or the generation of new ones on the basis of experiences that are individually specific" (Twardosz, 2012, p. 100). While experience-expectant plasticity has sensitive periods and usually ends around 18 years of age, experience-dependent plasticity continues throughout the whole lifespan of a person.

With regard to the individual and sociocultural layers, Sawyer (2014, pp. 8–10) sums up the following key points for learning as we know it: The starting point of learning is to use *prior knowledge* and build on that, adding, constructing, and creating new knowledge and correcting possible misunderstandings. To support this construction of knowledge, learning is *scaffolded*, that is, various methods are used to support the learning process. This means that the learner is given the opportunity to construct knowledge herself and that teachers abstain from giving a solution. This construction process is done by the learner by establishing an internal and external dialogue and using different techniques to *externalize* and *articulate* during the learning process. We can understand this dialogue as supporting *reflection*, which, together with the process of *stabilization*, is a core part of developing functional concepts. Externalization and articulation are concrete activities that gradually become rich, *abstract and functional concepts*, which can be used later and transferred to other situations. This view conceptualizes learning as a living process, in which learners actively participate, externalizing and articulating their own understanding. Several metaphors are used to discuss this, for example, the earlier mentioned knowledge-creation learning metaphor and knowledge-building learning, which emphasize the social emergent, self-organizing character of learning and cognition, as mentioned earlier (Pavela & Hakkarainen, 2005; Scardamalia & Bereiter, 2014).

One problem with many of the words used in this description of learning, such as reflection and articulation, is that they are often interpreted in a way that emphasizes mental cerebral activities — higher-order reflections — often mediated and stabilized with words. The stabilization "involves drawing a demarcation line around a phenomenon that is in flux [...] often achieved by naming, that is, imposing a linguistic structure on experience," as Greeno and Engeström (2014) formulate it in their activity theory perspective, drawing on Cussins (1992, pp. 677, 679–680). Cussins, in turn, referred to Latour's concept of "black-boxing" (1987) to describe this mental activity, that is, to put a demarcation line or a box around a complex phenomenon for easier access to it later. Greeno and Engeström later modified this statement: "But concepts are not merely verbal or symbolic labels or definitions. In particular, functional concepts, embedded in the practices of an activity system, are distributed among material artifacts and embodied enactments of the participants" (2014, p. 144). Still, it is an example of the seeming hegemony of verbal language often found in schools and in studies of learning, in which thoughts or concepts that can be mediated with words are given more weight than others. This is also linked to the old philosophical distinction between body and mind. In spite of several persuasive accounts to the contrary (see, for example, the account of Dewey's argument put forth by Bresler, 2004), the lingering bias that cognition is a mental activity, somehow separated from the body, remains. The consequences of these perspectives are easy to find, from terminologies in curricula (Utdanningsdirektoratet, 2006), to the organization of classrooms in which children are required to sit quietly and not fidget in order to concentrate, to verbal tests of competencies.

The problem with both these issues — the mind–body separation and the seeming hegemony of verbal language — is that they contradict what we know about cognition on the cerebral layer. The new technologies used in neuroscience, which allow researchers to study a living and processing brain, are currently leading to significant expansion of our understanding of mental activities that we do not consciously register or cannot put into words. Before these technological advances, such as fMRI and EEG among others, studies of the brain necessarily depended on observations and interviews with persons, in particular with patients with specific neural damage, followed by studying their brains after the subject died. This means that the knowledge Cussins and Latour had of concepts and cognitive learning, although extensive and precise, was probably based on dead brains and filtered through means of verbal language. When Cussins wrote that attaching a linguistic structure to this phenomenon is one familiar and important way of stabilizing learning, he leaned on the linguistic structure to make conceptual "trails provided for the possibility of predication." Recent accounts in neurolinguistics present detailed and convincing descriptions of how such stabilizations are developed, for example, the term "linguistic handles," as described by Schilhab (2017). Yet, through the study of the living brain today, it is possible to describe how we make conceptual trails by other means than verbal, such as how visual stimuli are encoded and decoded by areas of the brain that are similar, but separate, from the lingual areas (Broca's and Wernickes' areas). This incidentally aligns well with Merleau-Ponty's precise descriptions the phenomenology of perception almost seventy years ago (Merleau-Ponty, 1962). This new knowledge of the cerebral layer makes it possible to reassess how we understand reflecting, stabilizing and even communicating. This is in synch with the neurobiological definition of cognition as "a term that includes all mental processes. Perception, motor planning, thought, emotion, and executive function are all part of cognition. The components of cognition are each supported, either in part or wholly, by the cerebral cortex. Thus, one can view cognition as the total output of the cerebral cortex" (Mason, 2011, p. 284).

Today there is a broad scientific consensus that *cognition is situated*, in the sense that it takes place in a real-world environment and involves perception and action (Kiefer & Trumpp, 2012; Varela, Vermersch, & Depraz, 2003; Wilson, 2002). It is also *time pressured*: we cannot process everything, so we are dependent on filtering techniques that allow us to accomplish as much as possible without consciously evaluating every sensory input. In addition, because of this time pressure, we *off-load cognitive work onto the environment*; that is, we use the environment to hold information in order to "reduce cognitive workload," for example, by counting on our fingers, making visual representations, gesturing, etc. Further, researchers on cognition understand that *cognition is for action*. That is, that we process information in order to engage with the environment, see also the descriptions of the socially extended mind in Markauskaite and Goodyear (2016, p. 15, 132). However, at the same time, offline cognition, our abstract thoughts and memories, or even processing of information that we hear or see, engages task-appropriate sensorimotor areas in the brain — so even *offline cognition is body-based*. For example, when we see someone stumble and cut their knee, we can draw on previous experiences of falling and bleeding and relate to how it feels. This knowledge is also used in studies on how we learn and solve abstract mathematical tasks (e.g. Goodman, Seymour, & Anderson, 2016) and how gesturing facilitates creative thoughts (e.g. Lewis, Lovatt, & Kirk, 2015).

In this definition, all cognition is embodied in the sense that the input and output is the result of the mind–body interaction. It is therefore not useful to separate the mind and the body; rather, it is one entity: the bodymind, serving both online and offline cognitive activities. Hence, the term "embodied cognition." Actually, following this logic, the term embodied cognition, as such, may actually be redundant. The same can be said of the term "embodied learning," which, as a process of change, is an activity conducted on five levels of complexity and has a biological and embodied basis. Like the term embodied cognition, embodied learning confronts the cognitive representationalist conception of cognition that "neglects the inseparable co-determining of mental representations from bodily sources" (Schilhab, 2017, p. 4; Shapiro, 2014). However, using the term embodied learning points at these developments in our understanding of how the brain works and what cognition is. Used here as a theoretical lens, it points towards learning as situated, including both mental and physical processes.

2. Part 2. Using embodied learning as a tentative analytical tool to unpack a practical aesthetic making activity

With this lens of embodied learning in place, we can return to make activities in arts and crafts in Nordic countries, which has a strong emphasis on making things, often within a framework of a project that is developed from an idea to a finished product (Lindfors, 1992; Randers-Pehrson, 2015). We can approach this through the example of a girl, 7 years old, making flutes out of green willow (Figure 5).

Figure 5. Making a flute.

Carving entails a large variety of sensory perceptions and motor outputs, or actions. We do not consciously register everything; we filter and turn our attention towards what we want to register in a particular situation. This ability to efficiently filter what we pay attention to is what makes it possible to function; it is a condition for existence. One interesting function at play here in our girl as she carves, is called *thalamic attention* (Mason, 2011). The visual areas in our cortex receive information from the retina in the eyes through an area called the thalamus. The thalamus translates the visual signals to a neural signal that the cortex can interpret. The same nerve in the thalamus also receives information from the visual areas in the cortex and brainstem about what we expect to see and tells the retina what to look for. This is a feed-forward process that forms our projections and our preconceptions. Called a *perceptual habit*, it makes it possible for us to quickly identify information. Neurobiologists call it the mushroom hunt effect: the developed skill to identify a chanterelle between yellow leaves on the forest floor (Mason, 2015). The thalamus thus controls sensory input and perception from all the senses, except olfaction. Our little carver in Figure 5 deliberately focuses her attention on the knife edge and the wood. Experts in woodcarving will have a much more acute sense of deliberate attention and could purposefully stroke over a piece of wood to register how green it is or where there are notches that needs smoothing (haptic perception), or see with a quick glance a knife hidden under a heap of woodchips on the floor (visual perception). An example of such differences between experts and novices' trained perception skills, is documented by Mueller, Winkelmann, Krause, and Grunwald (2014) in their study of manual therapists' haptic perception skills.

Another way our cognition deals with time pressure is task delegation. Even though a big part of our cerebral cortex is dedicated to registering sensory input and perceiving it and to controlling and modulating motor output, not all coordination or modulation of motor movement is going on there. Much of what is going on — both our sensory perceptions and our motor responses, for example when holding a knife — is controlled by a part of the brain called the cerebellum (Gulliksen, 2015; Mason, 2011). The girl holds the knife in her right hand and the piece of willow in her left hand. She places the knife in the right(ish) position and pushes it forward. She is sensing the hard wood, the soft bark, the moist sap. While carving, motor areas in her cerebral cortex send information, via the cerebellum, to the muscles in the arm to push forward and downward. At the same time, these motor areas send information to the cerebellum that it has sent this information to the muscles in the arm, and the muscles in the arm send information to the cerebellum that it has indeed received this message. After making the movement, the muscles send a message back to the cerebellum: "I have done this movement." The cerebellum registers whether there is any discrepancy between the sent message and what has been done: for example, the wood was too hard and the cut was not deep enough. Such a discrepancy results in the cerebellum adjusting the message to the muscle in the next cut, adjusting the amount of force applied to the knife. This is, of course, just a part of what is going on, but it presents some core features of cerebellar activity. This receiving and sending of information is organized in a closed circuit between interlinked neurons, generating what neuroscientists tentatively refer to as a *central pattern generator (CPG)* (Mason, 2015). This CPG is also at work in other patterned movements, such as walking. This circuit is one of several features that effectively filter what we consciously control, able to act independently to fulfil the intentions of the maker and adjust output when needed, similar to how we adjust our steps when walking on different surfaces, such as tarmac, gravel or a forest path (Gulliksen, 2015). The CPG is understood as being a part of cerebellar learning; it is a form of learning on the *cerebral* and *cell layer*. The girl learns more about carving by repeating this action. Based on what we know about neuroplasticity, we must assume that her brain circuits are changing. Signals move between neurons and new paths are made, creating rich experiences that she can use later.

Next, describing the girl's learning on the *individual layer* of complexity, we can see that she is using her *prior knowledge* gained from previous carving experiences. Knowledge about how to carve resides in her body. She knows how to hold the knife, how to use her hands for strength, direction and control, how to stand, and how to be safe. As such, her motivated activity of carving is supported with resources (knife and wood) that make it possible for her to reach her goal (Greeno & Engeström, 2014). She is *scaffolding* her new experience by comparing what she is doing with what she has done earlier, looking on another flute to compare her work, asking questions about where-to and how-to (Reiser & Tabak, 2014), verbally, but also by looking, showing, pointing and touching. When she makes a mistake and cuts the mouthpiece too long, she herself registers the difference and starts again. She is *externalizing* her idea of how to make the flute by going through the steps, to some extent *articulating* by words ("I do this"), but mostly by making the actual cuts, holding, turning, looking and being in dialogue with the material. She is *reflecting* on what she is doing, by identifying micro-discoveries (Fredriksen, 2011) when she negotiates between her knife and her twig. Her hands are doing the thinking, adjusting grip and position of the knife. For her, out in the woods, this is a *concrete activity*, yet she is also developing *abstract concepts*: her ideas of a flute, how sound is made, how sap flows up into the branches of a tree in the spring, how some woods have sap that tastes sweet, and much more. As such, she is learning through making objects (Markauskaite & Goodyear, 2016, pp. 198–201; 209–220) actively using various techniques of online cognition and metacognition (Winne & Azevedo, 2014), identifying and overcoming problems in reaching her goal, and is thus engaged in what Ohlsson describes as the non-monotonic form of skills learning, adaption (Ohlsson, 2011, Chapter 6).

2.1. Making activities in the bigger picture of cognitive and behavioural development

Making activities in practical–aesthetic subjects, are always — in one way or another — giving us experiences that are multimodal and linked to our meaning-making as individuals and as social and cultural beings. As such, they are rich and complex, they take time, and they are dependent on several processes that filter out less relevant information to reduce cognitive load. Here, two of these filtering processes were mentioned: thalamic attention and the patterns of sensorimotor modulations generated in the cerebellum.

As we gradually acquire a skill, moving from novices to experts, we develop our offline thinking, our abstract concepts could be said to be scaffolded and stabilized as functional concepts embedded in the practices of an activity. This is in line with the notion that offline thinking is supported by activity in sensory-motor areas of the brain (Schilhab, 2017; Wilson, 2002, p. 635). At the same time, studies show that an expert's brain processes information as higher order tasks, with less activity in motor areas and sensory areas of the cerebral cortex when doing a motoric task than a novice's brain during the same task (Sawyer, 2014, p. 628). This indicates that the rich and prolonged active experience of the expert has developed their habits and patterns in a way that leaves available cognitive processing capacity to think about something else during the making process, unlike our 7-year-old novice girl, who is dependent on purposeful, targeted attention focused intently on her arms and legs and knife.

We recognize this description of the development of expertise in research on the organism (individual) layer, for example, from pedagogy (Dreyfus & Dreyfus, 1980; Hetland, Winner, Veenema, & Sheridan, 2013; Sheridan, 2011) and philosophy (Merleau-Ponty, 1962). There is thus a possible consistency between the two layers of complexity. Future studies linking or translating between the individual and cerebral layers could look at this to understand learning through prolonged sensory-motor engagement and how it leads to skills, such as that demonstrated by the expert carpenter who uses her hand to check whether the curve on the chair she's making is just right.

Further, the expert knowledge, the skilled awareness of the master, is also related to what Polanyi called *tacit knowledge* (1966), which often is expected to be "made explicit" by putting it into words. Drawing upon the logic of downward compatibility from the proposed layered abstraction framework, we argued earlier that it is not necessary to make the tacit explicit in order to learn it or stabilize it. Rather, *functional concepts* are developed through the making activity and prolonged engagement with the materials. In that activity, meaning is made in the reciprocal relationship between maker and material, maker and socio-cultural surrounding, via diverse examples, scaffolding tools and materials. The cerebellar learning of the 7-year-old girl can be seen as one example of a stabilizing pattern beginning to be generated, giving a rich experience of materials supporting abstract thinking (see also Groth, 2017). These experiences are necessary to develop a conceptual and behavioural repertoire (Huotilainen, 2016), and they are established phenomena in the cell/cerebral layer. The logic of *downward compatibility* demands that learning on the individual and sociocultural levels must be consistent with this, although it cannot predict what will actually happen because of the logic of *upward unpredictability*. It is therefore difficult to draw extensive conclusions on the impact of making activities on cognitive and behavioural development in general. However, these rich experiences give a foundation for cognition, for developing eye–hand coordination, and, in a broad sense, for providing rich opportunities to see that your actions cause something else to happen. This is also a social act, providing the opportunity to co-create meaning alone and with others. Such rich experiences give us a vocabulary — not only lingual, but with multiple forms of representations, with a variety of functional concepts — that is used when we learn how to represent and make ourselves through these languages. This can thus be useful for general education and the bigger task we have of "bildung," supporting young people's gradual development towards becoming responsible human beings (Klafki, 2001; von Oettingen, 2016).

3. Concluding remarks

We do not yet fully know how making matters or why. But, when seen from an embodied learning perspective, practical aesthetic making activity includes types of learning activities that are important for cognitive, behavioural and sociocultural development. As a conceptual piece, this article aims to bring together different theoretical frameworks and to begin exploring possible implications of such frameworks in order to initiate the start of a "meaningful prescriptive translation" that "may inspire, constrain, or describe educational practices" (Palghat et al., 2017, p. 209). It is, for example, possible to visualize future empirical studies analyzing and discussing making activities across cerebral, individual and sociocultural levels. At least three strands of future research topics within this framework could be highlighted as promising: (a) empirical studies of the phenomenon embodied by making itself, exploring and expanding previous phenomenological studies from the individual layer to the cerebral layers and below; (b) empirical studies of the learning that goes on in and through embodied making, for example, the sensorimotor and cognitive activity integration (Schilhab, 2017) between subject, context and artefact (wood, tool); or the way the negotiation activity carries a promise to facilitate non-monotonic, that is, deep learning (Ohlsson, 2011) and (c) studies on how engaging in making activities leads to structural and functional changes on the levels of cell, cerebral, individual and sociocultural in order to look for possible transfer of the learning in embodied making to other domains.

All three strands of possible future research could generate useful insights for the learning sciences; however, the last one could be the most immediately relevant for general education. Consider one specific and timely example: how to support teachers' choice of form (von Oettingen, 2016) in the twenty-first century classroom. Active, hands-on learning activities, in the tradition stemming from Dewey (1958) and Eisner (1998), are now revitalized as makerspaces, FabLabs (https://tltl.stanford.edu/projects/fablabschool), in both regular classrooms and other non-school centres of learning and making. Such spaces present the learner with the possibility of experiencing being a maker in this sociocultural context. However, these learning spaces varies in form and content, for example, the extent by which technological and virtual digital technologies (programming, coding etc.) versus more traditional, concrete material craft techniques (carving, welding, sewing) are used. Based in the framework of embodied learning described in this article, it is possible to recognize how the versions of learning space and type of making activity influence the learner's sensorimotor interaction differently. Studies on embodied making and learning in these spaces could generate knowledge of what these differences mean for the learner on cell, cerebral, individual and sociocultural levels of learning, using a between-level translational approach. This kind of knowledge can support the teachers' choice of form as well as their understanding and activation of their role in this professional practice (Green & Hopwood, 2015; Markauskaite & Goodyear, 2016, p. 142).

This article is a first opening to begin unpacking knowledge on practical aesthetic making activities that is relevant to future studies. The theoretical lens of embodied learning and the possibilities of translational research between layers of complexity described herein have highlighted examples of how this knowledge could support progress in understanding and critically assessing making and learning activities in twenty-first century schools.

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References

AECEA. (2009). *Arts and cultural education at school in Europe*. Brussels: Education, Audiovisual and Culture Executive Agency.
Bamford, A. (2006). *The wow factor: Global research compendium on the impact of the arts in education*. Münster: Waxmann.
Bresler, L. (2004). *Knowing bodies, moving minds: Towards embodied teaching and learning*. Dordrecht: Kluwer.
Bronfenbrenner, U. (1979). *The ecology of human development: Experiments by nature and design*. Cambridge, MA: Harvard University Press.
Cussins, A. (1992). Content, embodiment and objectivity: The theory of cognitive trails. *Mind, 101*(404), 651–688. https//doi.org/10.1093/mind/101.404.651
Dewey, J. (1958). *Art as experience*. New York, NY: Capricorn.
Donoghue, G. M., & Horvath, J. C. (2016). Translating neuroscience, psychology and education: An abstracted conceptual framework for the learning sciences. *Cogent Education, 2016*(3), 1–10.
Dreyfus, S. E., & Dreyfus, H. L. (1980). *A five-stage model of the mental activities involved in directed skill acquisition*. Washington, DC: Storming Media. https//doi.org/10.21236/ADA084551
Düvel, N., Wolf, A., & Reinhard, K. (2017). Neuromyths in music education: Prevalence and predictors of misconceptions among teachers and students. *Frontiers in Psychology, 8*(629). doi:10.3389/fpsyg.2017.00629
Eisner, E. W. (1998). Does experience in the arts boost academic achievement? *Journal of Art & Design Education, 17*(1), 51–60.
Engeström, Y., Miettinen, R., & Punamäki-Gitai, R.-L. (1999). *Perspectives on activity theory*. Cambridge: Cambridge University Press. https//doi.org/10.1017/CBO9780511812774
Fredriksen, B. (2011). *Embodied experience with three-dimensional materials and the negotiation of meaning in early childhood education* (PhD). Oslo School of Architecture and Design, Oslo.

Goodman, S. G., Seymour, T. L., & Anderson, B. R. (2016). Achieving the performance benefits of hands-on experience when using digital devices. A representational approach. *Computers in Human Behavior, 2016*(59), 58–66. https//doi.org/10.1016/j.chb.2016.01.006

Goswami, U. (2006, May). Neuroscience and education: From research to practice? *Nature Reviews Neuroscience*, 406–413. doi:10.1038/nrn1907

Green, B., & Hopwood, N. (Eds.). (2015). *The body in professional practice, learning and education* (Vol. 11). New York, NY: Springer.

Greeno, J. G., & Engeström, Y. (2014). Learning in activity. In R. K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences* (Vol. 2, pp. 128–147). Cambridge, MA: Cambridge University Press.

Groth, C. (2017). *Making sense through hands. Design and craft practice analysed as embodied cognition* (PhD). Aalto University, Helsinki.

Gulliksen, M. S. (2015). *The role of cerebellum in woodcarving - An exploration of neurobiological perspectives on wood carving*. Paper presented at the Eksig 2015: Tangible Means – Experiential Knowledge through Materials, Kolding.

Hetland, L., Winner, E., Veenema, S., & Sheridan, K. M. (2013). *Studio thinking 2*. Amsterdam, NY: Teachers College Press.

Huotilainen, M. (2016). *Keynote: Why our brain loves craft*. Paper presented at the Make it NOW, NordFo-conference 2016, Rauma. Retrieved from http://bit.ly/2rZp9Bz

Ingold, T. (2013). *Making: Anthropology, archaeology, art and architecture*. London: Routledge.

Kiefer, M., & Trumpp, N. M. (2012). Embodiment theory and education: The foundations of cognition in perception and action. *Trends in Neuroscience and Education, 1*(1), 15–20. doi:10.1016/j.tine.2012.07.002

Klafki, W. (2001). *Kategorial dannelse bidrag til en dannelsesteoretisk fortolkning av moderne didaktikk* [from: Studien zür Bildungstheorie und Didaktik], 1959, Oslo: Gyldendal Akademisk.

Latour, B. (1987). *Science in action: How to follow scientists and engineers through society*. Milton Keynes: Open University Press.

Lewis, C., Lovatt, P., & Kirk, E. (2015). Many hands make light work: The facilitative role of gesture in verbal improvisation. *Thinking Skills and Creativity, 2015*(17), 149–157. https//doi.org/10.1016/j.tsc.2015.06.001

Lindfors, L. (1992). *På väg mot en slöjdpedagogisk teori : paradigmutveckling och kunskapsbehållning : sammanfattning av tre studier* [Developing a sloyd-pedagogical theory: paradigms and knowledge status] ((Rapporter från Pedagogiska fakulteten, 34/1991, 136 pp.). Vasa: Åbo Akademi, Institutionen för lärarutbildning/Institutionen för pedagogik.

Markauskaite, L., & Goodyear, P. (2016). *Epistemic fluency and professional education - Innovation, knowledgeable action and actionable knowledge*. Dordrecht: Springer.

Mason, P. (2015). *Understanding the brain: The neurobiology of everyday life - lectures 1–10*. Chicago, IL: The University of Chicago.

Mason, P. (2011). *Medical neurobiology*. Oxford, NY: Oxford University Press. https//doi.org/10.1093/med/9780195339970.001.0001

Merleau-Ponty, M. (1962). *Phenomenology of perception*. (C. Smith, Trans.). London: Routledge.

Michl, J., & Dunin-Woyseth, H. (2001). *Towards a disciplinary identity of the making professions: The Oslo millennium reader*. Oslo: Oslo School of Architecture.

Mueller, S., Winkelmann, C., Krause, F., & Grunwald, M. (2014). Occupation-related long-term sensory training enhances roughness discrimination but not tactile acuity. *Experimental Brain Research, 232*(6), 1905–1914. https//doi.org/10.1007/s00221-014-3882-4

NRC. (Ed.). (2000). *How people learn. Brain, mind, experience and school*. Washington: National Academy Press.

OECD. (2009). *Education at a glance 2009: OECD indicators*. doi:10.1787/eag-2014-en

OECD. (2016). *Education at a glance 2016: OECD indicators*. doi:10.1787/eag-2014-en

von Oettingen, A. (2016). *Almendidaktik - mellem normativitet og evidens* [General education – between normativty and evidence]. Copenhagen: Hans Reitzels Forlag.

Ohlsson, S. (2011). *Deep learning: How the mind overrides experience*. Cambridge: Cambridge University Press. https//doi.org/10.1017/CBO9780511780295

Østerud, S. (1994). Handlingsteori: fra livsverden til habitus [Theory for action: From life-world to habitus]. In *Politica. Tidsskrift for politisk videnskab, 4*(26), 404–419.

Pavela, S., & Hakkarainen, K. (2005). The knowledge creation metaphor – An emergent epistemological approach to learning. *Science & Education, 14*(6), 535–557. https//doi.org/10.1007/s11191-004-5157-0

Palghat, K., Horvath, J. C., & Lodge, J. M. (2017). The hard problem of 'educational neuroscience'. *Trends in Neuroscience and Education, 2017*(6), 204–210. https//doi.org/10.1 016/j.tine.2017.02.001

Polanyi, M. (1966). *The tacit dimension*. London: Routledge & Kegan Paul.

Purves, D., Augustine, G. J., Fitzpatrick, D., Hall, W. C., LaMantia, A. S., & White, L. E. (Eds.). (2012). *Neuroscience* (5th ed.). Sunderland, MA: Sinauer Associates.

Randers-Pehrson, A. (2015). *Tinglaging og læringsrom i en kunst- og håndverksdidaktisk kontekst.* [Making things and learning in an art and craft educational context] (PhD Doctoral Thesis), University of Oslo, Oslo.

Reiser, B. J., & Tabak, I. (2014). Scaffolding. In R. K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences* (2nd ed., pp. 44–62). Cambridge: Cambridge University Press.

Sawyer, R. K. (2014). Introduction. In R. K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences* (2nd ed., pp. 21–43). Cambridge: Cambridge University Press. https//doi.org/10.1017/CBO9781139519526

Scardamalia, M., & Bereiter, C. (2014). Knowledge building and knowledge creation: One concept, two hills to climb. In S. C. Tan, H. J. So, & J. Yeo (Eds.), *Knowledge creation in education* (pp. 35–52). Singapore: Springer.

Schilhab, T. (2017). *Derived embodiment in abstract language*. Cambridge: Springer. https//doi.org/10.1007/978-3-319-56056-4

Shapiro, L. (2014). *The Routledge handbook of embodied cognition*. London: Routledge.

Sheridan, K. M. (2011). Envision and observe: Using the studio thinking framework for learning and teaching in digital arts. *Mind, Brain, and Education, 5*(1), 19–26. doi:10.1111/j.1751-228X.2011.01105.x

Twardosz, S. (2012). Effects on experience on the brain: The role of neuroscience in early development and education. *Early Education and Development, 23*(1), 96–119. doi:10.1080/10409289.2011.613735

Utdanningsdirektoratet [Norwegian Directorate for Education and Training]. (2006). *Læreplaner* [Curricula for the primary and secondary eduction]. Oslo: Utdanningsdirektoratet. Retrieved November 14, 2017, from https://www.udir.no/laring-og-trivsel/lareplanverket/finn-lareplan/#&english

Varela, F. J., Vermersch, P., & Depraz, N. (2003). *On becoming aware: A pragmatics of experiencing*. Philadelphia, PA: J. Benjamins.

Wall, M. (2014). *How neuroscience is being used to spread quackery in business and education*. Retrieved from https://theconversation.com/how-neuroscience-is-being-used-to-spread-quackery-in-business-and-education-30342

Wenger, E. (2008). *Communities of practice: Learning, meaning and identity*. Cambridge: Cambridge University Press.

Wilson, M. (2002). Six views of embodied cognition. *Psychonomic Bulletin & Review, 9*(4), 625–636. doi:10.3758/bf03196322

Winne, P. H., & Azevedo, R. (2014). Metacognition. In R. K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences* (2nd ed., pp. 63–87). Cambridge: Cambridge University Press.

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